# Don’t lose your reputation

Ernst Fehr

Collective action in large groups whose members are genetically unrelated is a distinguishing feature of the human species. Individual reputations may be a key to a satisfactory evolutionary explanation.

When the Allied forces invaded Normandy during the Second World War, thousands of people were involved in the preparations and in the invasion itself; a similar number of Germans were probably involved in defending the occupied territory. War is a prime example of large-scale within-group cooperation between genetically unrelated individuals (Fig. 1). War also illustrates the fact that within-group cooperation often serves the purpose of between-group aggression. Modern states are able to enforce cooperation in large groups by means of sophisticated institutions that punish individuals who refuse to meet their duties and reward those who follow their superiors’ commands. The existence of such cooperation-enhancing institutions is very puzzling from an evolutionary viewpoint, however, because no other species seems to have succeeded in establishing large-scale cooperation among genetically unrelated strangers[1].

The puzzle behind this cooperation can be summarized as follows. Institutions that enhance within-group cooperation typically benefit all group members. The effect of a single group member on the institution’s success is negligible, but the contribution cost is not negligible for the individual. Why, therefore, should a self-interested individual pay the cost of sustaining cooperative institutions? More generally, why should a self-interested individual contribute anything to a public good that — once it exists — an individual can consume regardless of whether he contributed or not? On page 499 of this issue[2], Panchanathan and Boyd substantially advance the scope of reputation-based models[3–5] and show that individuals’ concern for their reputation may be a solution to this puzzle.

Evolutionary psychologists have sought to answer the puzzle of human collective action for decades. However, progress was limited because of a lack of commitment to mathematically rigorous theorizing. Many researchers erroneously thought that Trivers’s notion of reciprocal altruism[6], which Axelrod and Hamilton successfully formalized as a tit-for-tat strategy for two-person interactions, provides the solution to the problem. Trivers himself speculated that reciprocal altruism “may favour a multiparty altruistic system in which altruistic acts are dispensed freely among more than two individuals”. However, it is always easier to speculate than to provide a rigorous model, and the speculation is likely to be wrong in this case.

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Figure 1 **Call to arms. Why do humans cooperate with others who are not genetically related to them, particularly in large-scale activities such as the waging of war? Panchanathan and Boyd[2] suggest that each individual is motivated by the desire to maintain their reputation as a contributor to the public good.**

In the context of the problem of public-goods provision, a reciprocally altruistic individual is willing to contribute to the public good if sufficient numbers of other group members are also willing to contribute. Unfortunately, the presence of only a small number of defectors quickly causes cooperation to unravel if it is solely based on conditionally cooperative behaviour, because the defectors induce the conditional cooperators to defect as well. Theory and simulations suggest that reciprocally altruistic strategies can only sustain high levels of cooperation in two-person interactions[7]. Moreover, experimental evidence indicates that cooperation in public-good games typically unravels because it is not possible to discipline ‘free riders’ — those who take advantage of others’ cooperation — if only conditionally cooperative strategies are available[8].

In contrast to reciprocal altruism, the notion of altruistic punishment has been more successful in explaining collective action, because direct punishment disciplines free riders[8]. Altruistic punishers contribute to collective actions and are willing to sanction individual defectors even if they incur net costs by doing so. However, within-group selection in the presence of altruistic punishers favours cooperative individuals who do not punish defectors. Such individuals will never be punished — because they contribute to the collective action — but they also never bear the cost of punishing defectors. These pure cooperators are thus ‘second-order’ free riders because they do not contribute to the disciplining of the selfish individuals. Therefore, pure cooperators will crowd out altruistic punishers unless there is group competition that renders groups with a higher share of altruistic punishers more successful[9].

Panchanathan and Boyd’s contribution[2] solves this second-order free-rider problem by linking the notion of indirect reciprocity[3,4] with an individual's reputation for contributing to collective actions. An indirectly reciprocal individual helps another individual if the recipient of the help has a good reputation and if — by helping — the individual can himself acquire or maintain a good reputation. If helping accords a good reputation and individuals with a good reputation will also receive help when needed, the act of helping becomes a self-interested choice. Note that no direct reciprocal interactions are necessary in this case; the only prerequisites are that helping confers a good reputation and that people with a good reputation are helped in the future. In a pioneering experiment, Milinski *et al.*[10] showed that if potential donors in a game of indirect reciprocity are informed of a recipient's contribution in a previously played collective-action game, cooperative behaviour in the collective-action game is sustained at very high levels. Apparently, potential donors do not help those who fail to contribute to the public good but they assist those who contribute. This pattern of helping provides strong incentives for selfish individuals to contribute to the public good.

Inspired by this experiment, Panchanathan and Boyd provide a parsimonious evolutionary model by linking an indirect-reciprocity game with a game of collective action. The key element in their model is the shunning strategy. A shunner always helps a deserving recipient; if he does not, he loses his good reputation. However, the shunner can maintain his good reputation by refusing to help an undeserving recipient. A recipient deserves help if he is in good standing. In contrast, a recipient does not deserve help if he is in bad standing: that is, if he either did not contribute to the collective action or did not help a deserving recipient in previous interactions in the indirect-reciprocity game. Therefore, the shunners punish free riders who did not participate in the collective action without any cost to themselves because the shunners refuse to help free riders when they are in need. In fact, because the shunners save the cost of helping by their refusal to help, this form of punishment is in their self-interest. Thus, if a system of social norms based on the shunning strategy prevails, shunners face no selection pressures — and the second-order free-rider problem is solved.

A crucial element of the shunning strategy is that it rests on the recipients' behaviour in the collective-action game. Panchanathan and Boyd[2] show, however, that a shunning strategy cannot establish itself in a group where the helping decision is not linked to the cooperative decision in the collective-action game. Thus, a system of social norms that does not punish free riders by refusing to help them is just as stable as a system of norms that punishes free riders. A convincing evolutionary solution to the second-order free-rider problem therefore requires additional mechanisms. One such mechanism could be competition between groups with different social norms, because groups that successfully link the helping decision with individuals' behaviour in the collective-action game are better able to solve their collective-action problems. Group competition therefore does not serve as a mechanism for offsetting within-group selection pressures on shunners — because shunning is an individually advantageous strategy — but is merely a device for the selection of cooperation-enhancing social norms. ■

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**Materials science**

# A 'bed of nails' on silicon

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The future of electronics may rest on devices that integrate other semiconductors with silicon. A means of creating tiny semiconductor pillars on a silicon surface is now demonstrated.

Computers rely on silicon. Although other semiconductors have desirable features, in this context the materials properties of silicon are so outstanding that it is really the only choice for the large-scale integration of fast electronic devices. But there is a dark shadow over silicon, in that it produces no light. Many devices use light — simple ones, such as the solid-state diode lasers typically found in CD players, for example; and more complex ones, such as the light amplifiers used in long-range optical-fibre communication. Gallium arsenide or other more exotic semiconductors must be incorporated into these devices to generate light. In *Nano Letters*, Mårtensson *et al.*[1] present a new means of doing so.

Why is the lack of optical activity in silicon a problem? After all, CD players don't need much computational power. And computers don't need light. Or do they? The ever-decreasing size of transistors made of silicon means that the transit time for charge carriers through them (and hence their switching time) is increasing rapidly. The overall speed of a microprocessor will be more and more limited by the time delay inherent in the connections between individual transistors[2]. According to the International Technology Roadmap for Semiconductors[3], the traditional copper/dielectric-material system for interconnects will have to be replaced by some novel on-chip interconnect scheme beyond the year 2010.

Optical communication is very fast, so if communication between the far reaches of a chip were possible by optical means, the full advantage of size scaling could be realized. Hence there is a demand for faster on-chip data communication using opto-electronic components, such as light-emitting diodes made from aluminium, gallium, arsenic and phosphorus (elements from groups III and V of the periodic table that are commonly paired in semiconducting 'III–V' materials). These materials are optically active and can be grown as heterostructures (of different materials that are crystallographically linked) to form quantum wells and quantum boxes that emit coherent light through electrical stimulation. Their optical activity can be designed, as can the crystal growth sequence required to obtain it.

Because the fabrication of silicon devices and the process of heterostructure growth for lasers are well developed, devices that require both are typically manufactured using a hybrid technology — one that contains different chip sets of silicon and III–V circuits connected by wires. But it is easy to see that this approach fails to speed on-chip communication. For that, direct crystallographic integration of III–V heterostructures onto silicon is needed, preferably at the nanoscale.

Exactly this approach has now been demonstrated by Mårtensson *et al.*[1], who have grown optically active III–V nanowire heterostructures on silicon. The nanowires — which sometimes look like a bed of nails (Fig. 1) — are typically 2 μm long, with a base diameter of 50–100 nm. They have light-emitting sections grown into them and thus function effectively as light towers on the silicon substrate. These nanopillars, as well as being a beacon of hope for on-chip optical communication, open a variety of other communication applications by linking optical components with silicon-based circuitry.